Continental J. Environmental Sciences 3: 24 - 32, 2009

GEOELECTRICAL AND GEOCHEMICAL EVALUATION OF GROUNDWATER RESOURCES IN SAPELE METROPOLIS, WESTERN NIGER DELTA.

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ABSTRACT
A combination of geoelectrical and geochemical investigation was carried out in Sapele metropolis to ascertain the aquifer characteristics and geochemical parameters of the groundwater of the area,Ten (10) water samples were collected from hand-dug wells into sterilized containers for geochemical analysis. The geochemical parameters showed average values of 6.20 pH; 156.60µs/cm EC; 7.60mg/l TH ; 4.50mg/l Ca^{2+}; 4.20mg/L Mg^{2+}; 0.95mg/l K^{+}; 1.00mg/l Na^{+}; 0.87mg/l ∑Fe; 0.03mg/l Cu^{2+}; 0.04mg/l Cr^{2+}; 28.68mg/l Cl^{-} ; 5.40mg/l HCO_3^{-} ; 2.41mg/l NO_3^{-} ;0.80mg/l SO_4^{2-} and average sodium absorption ratio (SAR) of 1.36. The relative abundance of cations using these concentrations is in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} >$ ∑Fe $> Cr^{2+} > Cu^{2+}$ while those of anions are in the order $Cl^{-} > HCO_3^{-} > NO^{3-} > SO_4^{2-}$. Fifteen (15) vertical electrical soundings were carried out in the study area using Schlumberger electrode configuration. The result of the interpretation of the VES curves showed that the area is made up of four and five geoelectric layer and the average depth to the aquifer is 35.2m with resistivities ranging between 1229.4Ωm and 3816.3Ωm. All the concentration of the various parameters determined in the groundwater was relatively in accordance with WHO recommended standard for domestic uses except pH and ∑Fe. Cr^{2+} concentrations generally were below stipulated standard in most of Sapele metropolis, but the concentrations at Ugbeyiyi and Ugberikoko were above WHO maximum allowance limit of 0.05mg/l.

KEYWORDS: Domestic water, relative abundance, geochemical parameters, WHO, Sapele

INTRODUCTION

Domestic water supply in Sapele metropolis comes largely from groundwater found in large reservoirs called aquifers and it is accessed by wells (Price, 1985).

Water is ubiquitous in the natural environment but still there are some areas in which groundwater cannot be obtained in sufficient quantities due to factors like the porosity and permeability of the reservoirs (aquifers). Groundwater, even if present in sufficient quantities may be contaminated by dissolved natural chemical constituents which depends on the geochemical environment and source of groundwater. Thus proper precautions should be taken in such areas to reduce the risk of spending large sums of money in sinking abortive wells.

This paper discusses the results of a geoelectrical survey employing vertical electrical sounding (VES) and geochemical analysis of groundwater in Sapele metropolis. The interpretation of the acquired VES data reveals depth to water bearing formations (aquifers), their thicknesses, and resistivities. Also, the measured parameters from the geochemical analysis was compared with the WHO stipulated standard in order to assess their suitability for domestic and agricultural uses.

LOCATION, GEOLOGY AND HYDROGEOLOGY

Sapele lies on latitude 5^0 38′ E and 5^0 45′ E and longitude 5^0 30′ N and 5^0 37′ N (Fig.1) and covers an area of about 347 km^2.The study area lies within the Tertiary Niger Delta, which is stratigraphically made up of three major formations: Akata, Agbada and Benin Formations.The three formations were laid down under marine, transitional and continental environments respectively (Short and Stauble, 1967).

The Akata Formation which is the lowermost unit is 4000ft thick and made up dark grey sandy, silty shale and thin sandstone lenses. The Agbada Formation is made up of alternating sequences of sandstone and shale. This formation is 1000ft thick. The Benin Formation (topmost unit) is made up of over 90% sandstone with shale intercalation. The thickness of this formation is variable but generally exceeds 6000ft.

Unconsolidated coarse and gravelly sands constitute the aquiferous units that are unconfined, the basic groundwater recharge of the study area

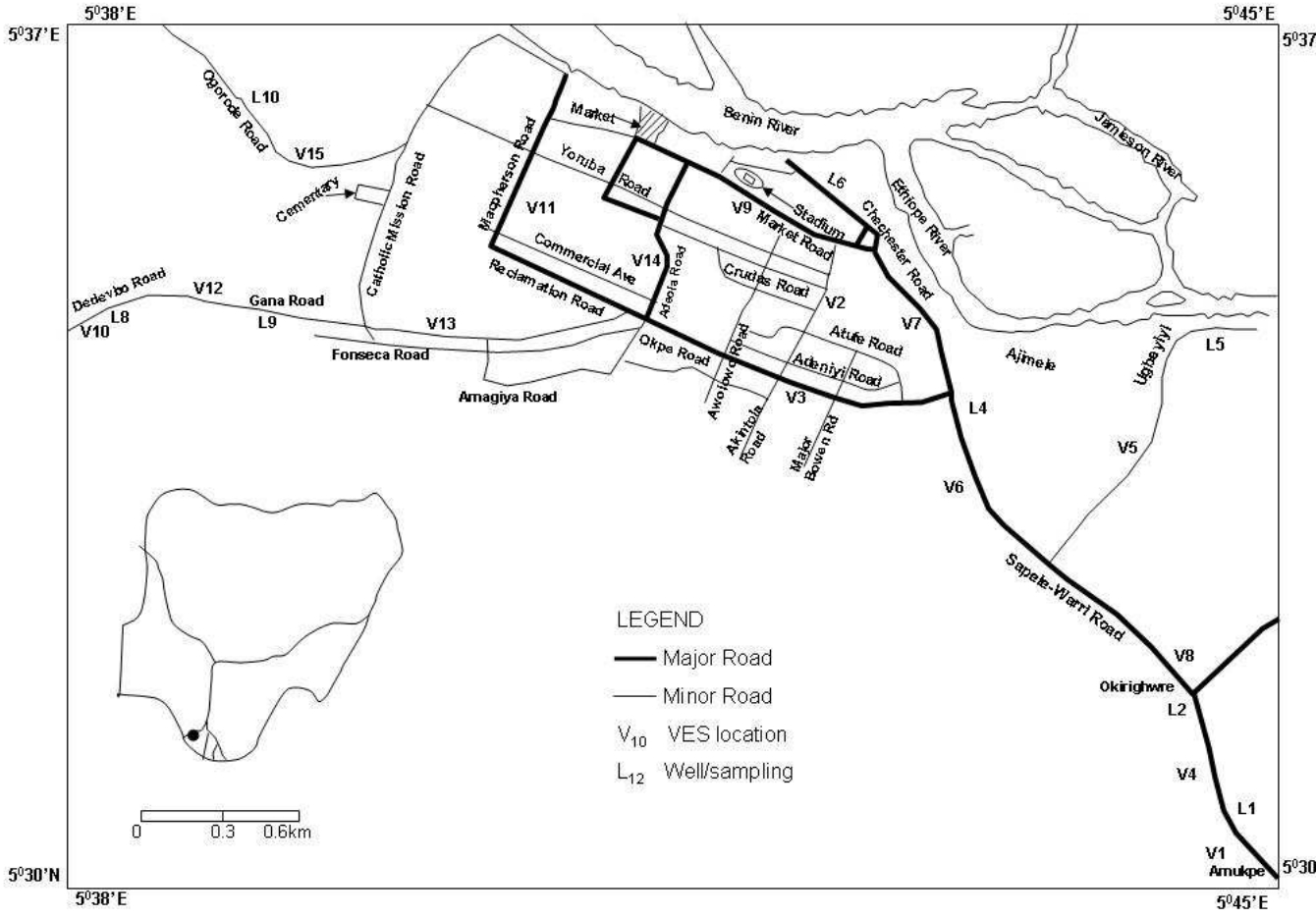

Fig. 1: Map of Sapele metropolis showing sampling/sounding locations

are from direct infiltration of rainfall into the ground and infiltration through rivers beds such as the Ethiope river and Mayuku creek (Offodile,1992). The map of Sapele metropolis indicating sampling and sounding locations is given in Figure 1.

MATERIALS AND METHODS.

Geoelectrical Investigation

Fifteen schlumberger vertical electrical soundings (VES) were made in the study area using an ABEM tetrameter SAS 1000 with maximum current electrode spacing (AB/2) of 225m. The apparent resistivity obtained from the field was plotted on a log-log graph paper

The initial interpretation of the VES data was carried out using the conventional partial curve matching techniques with two-layer master curves in conjunction with auxiliary point diagrams (Zhandov and Keller, 1994). The estimates of resistivities and thicknesses obtained from the partial curve matching were used as initial input to a computer programme that is based on optimization technique. Fig.2 and 3 shows examples of some sounding curves and their interpretation.

Geochemical Investigation

Groundwater samples were collected in sterilized polyethylene bottles from 10 locations (fig.1). Parameters such as pH, electrical conductivity, total hardness, total iron ($\sum$Fe), cations such as Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, Pb^{2+}, Cr^{2+}, Zn^{2+} and anions such as Cl^{-}, SO_4^{-}, HCO_3^{-} and NO_3^{-} were determined in the laboratory.

pH was measured with standard pH meter while electrical conductivity was measured with HACN conductivity meter. The Atomic Absorption Spectrophotometer methods were used to determine the concentrations of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Pb^{2+}, Cu^{2+}, $\sum$Fe, Cr^{2+}, Zn^{2+}, $S0_4^{2-}$, HCO_3^{-}, NO_3^{-} and Cl^{-}.

RESULTS AND DISCUSSION

The VES results (Fig.2 and 3) showed slightly different depths to the aquifer. At Amukpe (VES I and VES 4) the depths to the aquifer were 32.8m and 35.2m respectively while at Okirighwre (VES 8), the depth to the aquifer was 40.7m. The aquifer (fourth layer) in this area as shown in Fig.4 is unconfined and made up of gravelly sands. At Ugberikoko (VES 10), the depth to the aquifer was 38.2m and at Gana (VES 12) the depth to the aquifer was 28.6m while the depth to aquifer at Ogorode (VES 15) was 35.7m. The aquifer (fourth layer) in these parts as shown in Fig.5 are also unconfined but are made up of coarse sands.

The result from the geochemical analyses of groundwater samples are presented in Table 1.

The pH values ranged between 5.4 and 6.7. This indicates that the groundwater is acidic and that values fall below the minimum limit of 6.5 recommended by WHO (1998b). On the basis of the above, most of the groundwater sources can be regarded as quite acidic; such acidity has usually been associated with acid rain resulting from crude oil station flares (Ekakitie *et al*. 2000).

Total hardness ranged from 2.32mg/l to 20mg/l. According to Hem (1970), when the total hardness in water is less than 60mg/l (Table 2), it is classified as soft. Hence the groundwater in Sapele metropolis is acidic, soft and fresh.

The measured electrical conductivities of the investigated groundwater varied between 75µs/cm and 300µs/cm. The measured values of electrical conductivity were below the 1400µs/cm maximum permissible level stipulated by WHO (1984a).

For the major cations, Sodium (Na^{+}) concentration ranged from 8.53 -11.22mg/l, Potassium (K^{+}) 0.20 - 1.54mg/l, Calcium (Ca^{2+}) 1.42 -18.50mg/l and Magnesium (Mg^{2+}) 1.50 - 18.50mg/l. The concentrations of these cations in the investigated groundwater (Table 1) have been compared with the internationally recommended standard of WHO (1984a) and were found to be below these standard values.

Heavy metals such as Lead (Pb^{2+}) and Zinc (Zn^{2+}) were not detected in the groundwater during the analytical work and hence, show conformity to WHO recommended standards (WHO desired level for Lead is 0.01mg/l and Zinc is 0.1mg/l). The concentration of copper (Cu^{2+}) as well as the pH of water is regarded as toxic (Seim and Tischendorf, 1990). Copper (Cu^{2+}) was not detected in the groundwater at most sample locations except at Okirighwre, Okpe road, Ajogodo and Ugbeyiyi (Table 1), with concentrations ranging between 0.01mg/l and 0.05mg/l. These values are below WHO specification of 1.0 mg/l. Except for sample from Ugbeyiyi which shows ($\sum$Fe) concentration to be 0.25mg/l, concentrations of total iron ($\sum$Fe) at other sample points are quite high ranging between 0.36 -1.82mg/l which are above WHO maximum allowance limit of 0.3mg/l. Concentrations of chromium (Cr^{2+}) in groundwater sample varied between 0.01mg/l and 0.11mg/l and are generally below WHO maximum

allowance limit of 0.05mg/l except at Amukpe, Ugbeyiyi and Ugberikoko where the concentrations are above WHO standards.

The source of iron and chromium in the groundwater has not been ascertained but it may be due to industrial activities, refuse dumps and metal scraps along the river courses which are also source of groundwater and those naturally induced (i.e from the geology of the area) as reported by FEPA (1991).

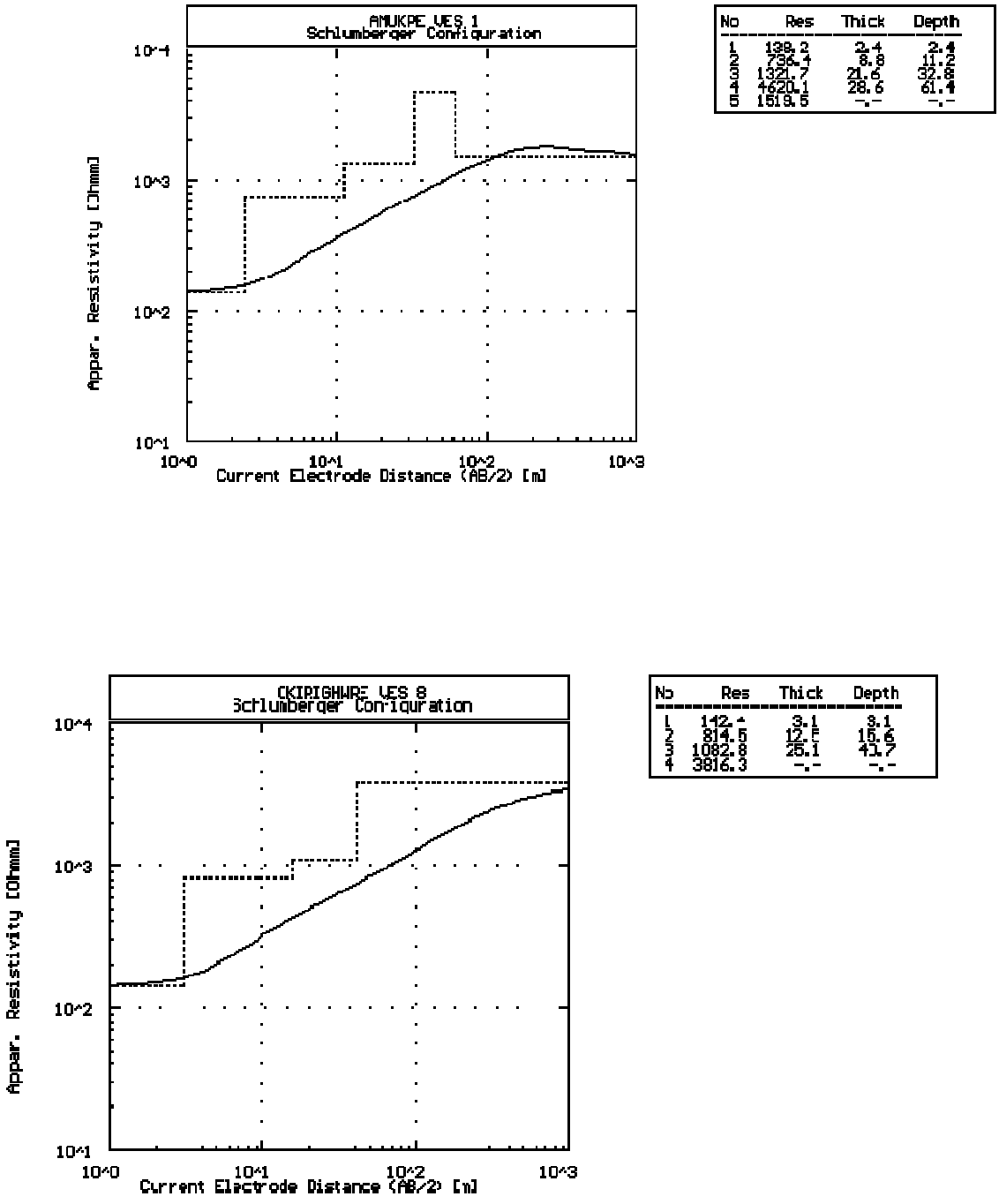

Fig 2: Typical VES Curves for Amukpe and Okirighwre

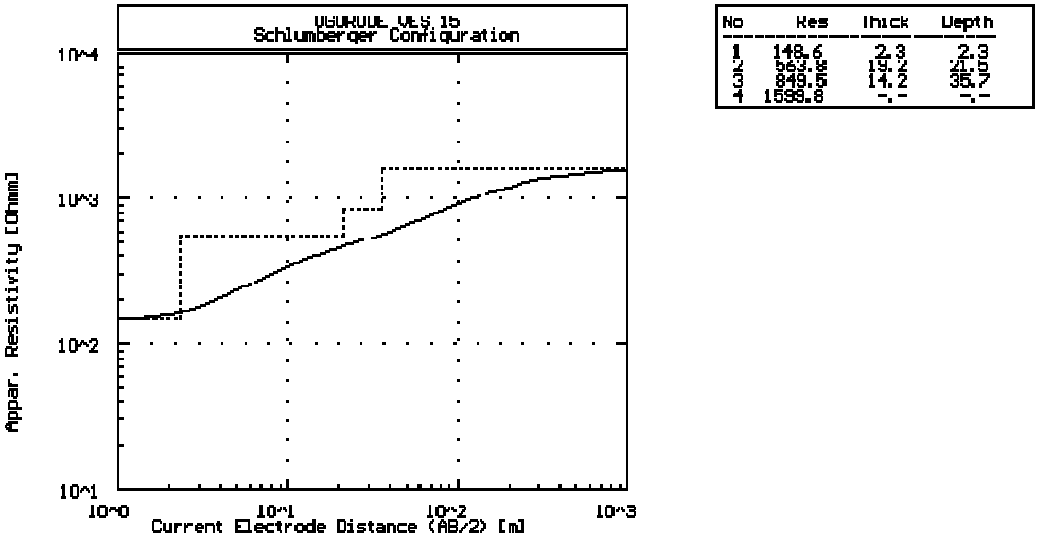

Fig 3: Typical VES Curve for Ogorode

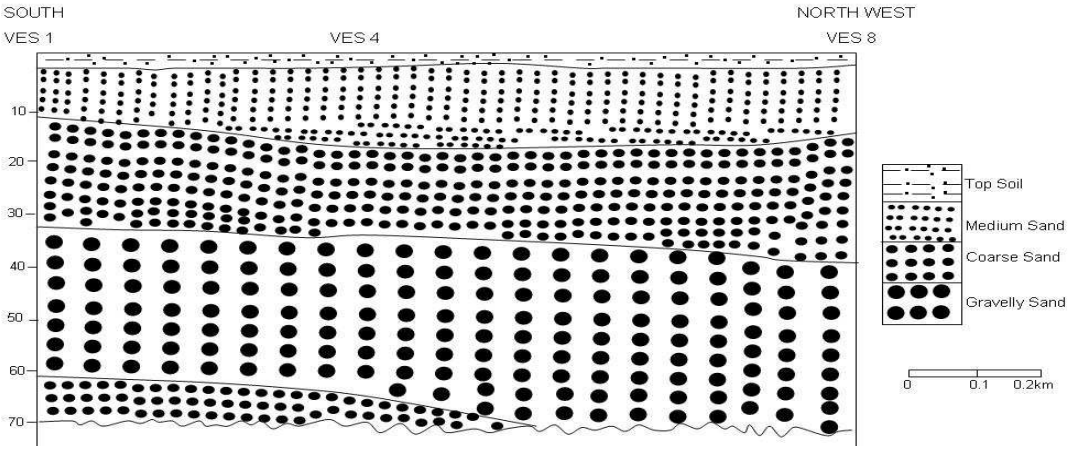

Fig 4: Typical geoelectric section for Amukpe and Okirighwre

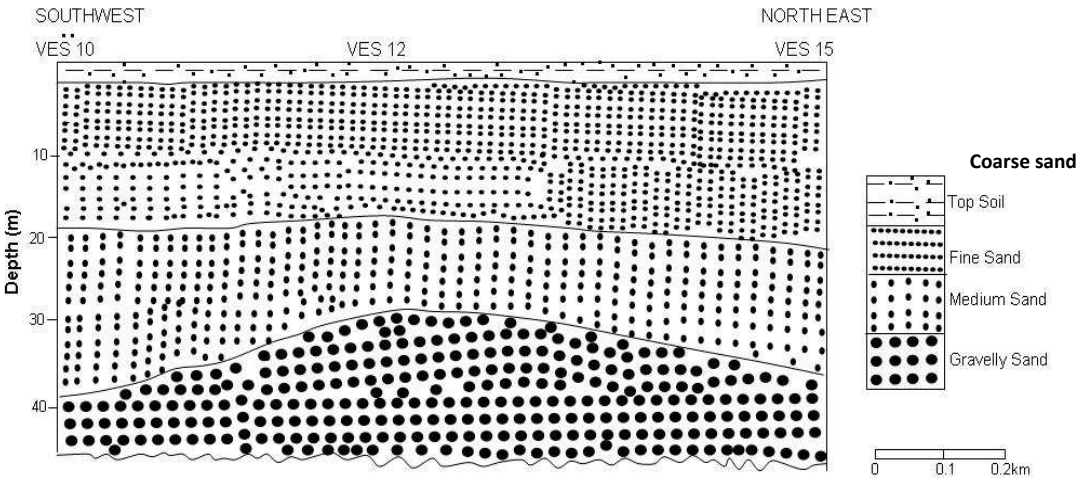

Fig 5: Typical geoelectric section for Ugberikoko, Gana and Ogorode

Table 1: Generalized result of the geochemical parameters of groundwater from Sapele metropolis

Parameters/ locations	Amukpe	Okirigwre	Okpe Rd	Ajogodo	Ugbeyiyi	Chechester Rd	Crudas Rd	Gana	Ugberikoko	Ogorode.
pH	5.90	6.40	6.70	6.00	6.30	5.80	5.70	5.40	6.80	6.60
Electrical Conductivity (µs/cm)	300	210	108	190	75	90	150	130	165	148
Total Hardness (mg/l)	4.62	3.96	14.60	30.00	4.32	5.00	2.30	2.77	2.85	6.00
Calcium (Ca^{2+}) (mg/l)	3.05	2.50	3.00	18.50	2.70	3.50	4.30	1.42	2.20	4.01
Magnesium (Mg^{2}) (mg/l)	4.27	3.40	1.62	5.00	2.30	1.50	18.50	1.86	2.00	3.70
Potassium (K^{+}) (mg/l)	1.54	0.20	0.48	1.52	0.92	0.64	0.84	1.25	1.05	1.06
Zinc (Zn^{2+}) (mg/l)	ND	ND	ND	N	ND	ND	ND	ND	ND	ND
Lead (Pb^{2+}) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper (Cu^{2+}) (mg/l)	ND	0.03	0.05	0.01	0.02	ND	ND	ND	ND	ND
Chromium (Cr^{2+}) (mg/l)	0.11	0.04	0.05	0.03	0.06	0.02	0.01	0.01	0.06	0.01
Sodium (Na^{+}) (mg/l)	9.00	9.80	11.80	11.60	9.50	8.96	9.25	10.30	11.22	8.53
Total Iron (∑Fe) (mg/l)	0.62	1.60	0.88	1.8	0.25	0.80	0.55	0.72	0.36	1.10
Chloride (Cl^{-}) (mg/l)	15.00	45.80	16.10	122.00	10.20	8.44	15.72	10.75	19.97	22.85
Bicarbonate (HCO_3^{-}) (mg/l)	4.03	6.52	9.20	7.2	3.45	3.40	8.33	3.95	3.20	4.65
Nitrate (NO_3^{-}) (mg/l)	1.96	2.88	2.24	2.72	1.28	2.24	1.86	3.01	2 .85	3.06
Sulphate ($S0_4^{2}$) (mg/l)	1.34	1.28	0.22	0.45	0.30	0.50	0.78	1.56	0.25	1.40
SAR	1.10	1.34	1.94	0.87	1.45	1.43	0.61	1.90	1.86	1.05

ND = No Detection

Table 2: Water class based on total hardness (After Hem, 1970).

Hardness mg/l	water class
0-60	Soft
61-120	Moderately hard
121-180	Hard
>180	Very hard.

All the determined anions Cl^-, $N0_3^-$, $S0_4^{2-}$ and HCO_3^- showed concentrations (Table 1) below those recommended by World Heath Organization's guideline, for drinking water quality (WHO, 1984a).

The suitability of groundwater in Sapele metropolis for irrigation purpose was determined using the Sodium Absorption Ratio (SAR). (Etu-Efeotor, 1981).

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}\left([Ca^{2+}] + [Mg^{2+}]\right)}}$$

Where, Na^+, Ca^{2+} and Mg^{2+} concentrations are in millimole/litre (mmol/l).

The value of Sodium Absorption Ratio (SAR) ranging between 0.61 and 1.96 indicate that the groundwater in Sapele metropolis is excellent for irrigation purposes (Table 3). The SAR values also showed that the ground water will not pose any serious problem to the soil when used for irrigation purposes. When the SAR value rise above 12 to 15, serious physical soil problems arise and plants have difficulty absorbing water (Munshower, 1994).

Table 3: Water class based on SAR (After Etu-Efeotor, 1981)

SAR	WATER CLASS
0-10	excellent
10-18	Good
18-26	fair
>26	poor

CONCLUSION

Investigations for locating high yielding aquifers were carried out in Sapele metropolis using geoelectrical method. The area has thick sediment cover consisting of mainly sandy layers serving as potential good aquifers which are basically unconfined. The average depth to the water bearing formation is 35.2m with resistivity values varying between 1229.4Ωm and 3816.3 Ωm.

From the result of the geochemical analyses, almost all the water quality parameters analysed were present in concentrations which were within the WHO permissible limit for drinking water.

Total iron ∑Fe and pH were the only parameter that was present in concentrations higher than WHO permissible limit for drinking water. Comparing the geochemical parameters of the various water sample

with WHO standards, the result showed that the groundwater in Sapele metropolis are chemically potable except for the location where the total iron ∑Fe and chromium (Cr^{2+}) contents were found to be above the maximum permissible levels. Since pH of groundwater can be improved through adequate treatment, the water quality of the area can be described as generally good for domestic and irrigational purposes.

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Received for Publication: 07/11/2008
Accepted for Publication: 24/03/2009